Thermodynamical Processes Associated with the Life-cycle of the Monsoon Intraseasonal Variability in CFES Integrations

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The equatorially trapped convective anomalies associated with the Madden-Julian oscillation (MJO) interacts with the mean monsoon during boreal summer resulting in north-northward migration of convective anomalies over the northern Indian Ocean and tropical west Pacific. First, in climate models, the necessary and sufficient conditions required for realistic simulation of monsoon intraseasonal variability will be summarized. Second, moisture and moist static energy budget diagnostics are applied to free runs of two versions of Coupled model For Earth Simulator (CFES) -difference between the two runs being changes made to cumulus convective schemes, particularly the vertical structure of entrainment. Third, budget diagnostics are applied to an AMIP-type simulation performed with the Atmospheric model For Earth Simulator (AFES). In the model simulations, the leading thermodynamical processes responsible for the monsoon variability will be discussed. Finally, results from CFES and AFES runs will be compared to understand (if any) the role of air-sea interaction in monsoon intraseasonal variability characteristics.

Keywords: Monsoon Intraseasonal variability, CFES simulations, Entrainment

Two dominant modes over the summertime western North Pacific and their interdecadal modulations

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Structures and dynamics of two dominant meridional teleconnection patterns over the summertime western North Pacific (WNP) in intraseasonal to interannual time scales are examined. One of them features a positive correlation between convective activity around the northern Philippines and lower-tropospheric circulation centered near Japan, and called the Pacific-Japan (PJ) teleconnection pattern. Preceding studies argued that this pattern could be regarded as a dynamical mode, which efficiently gain energy from background state. The PJ pattern is significantly correlated with El Niño-Southern Oscillation (ENSO) peaked in preceding winter. Through an empirical orthogonal function (EOF) analysis for over half a century of Japanese 55-year reanalysis (JRA-55), the PJ pattern outstands as the leading mode of lower-tropospheric vorticity. The second EOF mode features a positive correlation between convective activity centered at Guam of the Mariana Islands and lower-tropospheric circulation around the Bonin Islands. We therefore call it the Mariana-Bonin (MB) pattern. This pattern also gains energy from background state through barotropic and baroclinic energy conversion as efficiently as energy generation due to anomalous diabatic heating, and thus bears dynamical mode features. The efficiency, however, is less than in the PJ pattern, consistent with the dominance of the PJ over MB patterns. In addition, the MB pattern is highly correlated with ENSO in developing stage.
The two patterns have undergone significant interdecadal modulations. The PJ pattern amplified from the 1950s to 1980s, and then weakened until the 2000s. It is suggested that interdecadal changes of ENSO forcing of the PJ pattern via Indian Ocean and tropical WNP sea surface temperature anomalies are responsible for these modulations. The MB variance also shows interdecadal modulations but the changes are weaker than in the PJ pattern. As a result, the PJ pattern has degraded to the second EOF mode since the late 1990s, while the MB pattern has been promoted to the leading EOF mode instead.

Keywords: ENSO, Teleconnections

Wintertime meridional teleconnection associated with convective activity over the Maritime Continent

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Anomalous convective activity forced by tropical SST variability associated, for example, with ENSO influences the climate and weather in the extratropics. It has been known that El Niño (La Niña) tends to bring milder (colder) winter to East Asia, providing a statistical basis for wintertime seasonal predictions. However, ENSO variability is found to account only for nearly 60% of the interannual variance of convective activity around the maritime continent, and a significant fraction of the convective variability may therefore be uncorrelated with tropical SST variability. Through analysis of observational data for 1979/80-2011/12, the present study attempts to identify the tropical region where the interannual variability in seasonal-mean activity of SST-uncorrelated convection tend to be strongest and how effectively the variability can force atmospheric teleconnections into the extratropics if compared to ENSO-forced anomalous convection. At each location SST-correlated OLR variability was first identified by regressing seasonal-mean OLR anomalies linearly on the five leading PC time series of tropical SST variability. Defined locally as the residual, seasonal-mean anomalies in SST-uncorrelated OLR variability include no direct contribution from MJO. The leading EOF of the SST-uncorrelated OLR variability in boreal winter over the entire tropics accompanies the largest local variance around the maritime continent, where the variability reaches as much as a third of the ENSO-forced OLR variance. The associated atmospheric anomaly pattern differs considerably from that forced by ENSO, especially in the midlatitude north Pacific. The SST-uncorrelated convective variability around the maritime continent is found to exert remote influence on wintertime East Asian climate, which tends to be even slightly stronger than the ENSO influence. Our analysis thus suggests that the anomalous convective activity around the maritime continent uncorrelated with SST variability significantly limits the wintertime seasonal predictability over East Asia.

Keywords: East Asian winter monsoon, ENSO, seasonal predictability

Effects of the North Pacific subtropical SST front on the Baiu precipitation

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The Baiu/Meiyu front is manifested as a rain band and is one of the most remarkable features in the East Asia summer monsoon. It appears over the subtropical western North Pacific around late May and then subsequently migrates northward. Focusing on the subtropical SST front that extends almost zonally about 25°N in the western subtropical gyre, the present study examines its effect on the Baiu precipitation in late May using satellite observations and ERA-interim reanalysis data from 2002 to 2014.
The subtropical SST front has a clear seasonal cycle and becomes strong in May. The strong SST front enhances atmospheric baroclinicity and anchors cyclonic surface wind curls that occur intermittently at intervals of a few days. The wind curls are associated with subsynoptic low pressure systems embedded in larger, synoptic highs in the main storm track to the north (Kobashi et al. 2008). The climatology of the precipitation in late May reveals the two rain bands separated by the minimum in precipitation along the SST front. The moisture budget analysis shows that the observed two rain bands correspond well to the horizontal convergence of moisture flux. Dividing the moisture flux into a slowly-varying component and a high-frequency disturbance component, we find that disturbances cause the moisture flux divergence along the SST front and split the slowly-varying large-scale Baiu rain band into the two rain bands. Northerly winds from synoptic highs are locally enhanced behind the subsynoptic lows and carry dry air to the north of the SST front, causing the moisture flux divergence along the front. The subsynoptic lows along the subtropical front are each accompanied by convective rain, but their contribution to the climatological precipitation is outweighed by the effect of the northerly wind-induced moisture divergence.

Keywords: Subtropical SST front, Baiu front, precipitation

Quantifying the Intra-Regional Precipitation Variability in Northwestern China over the Past 1,400 Years

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There has been a surge of paleo-climatic/environmental studies of Northwestern China (NW China), a region characterized by a diverse assortment of hydro-climatic systems. Their common approach, however, focuses on “deducing regional resemblance” rather than “exploring regional variance.” To date, efforts to produce a quantitative assessment of long-term intra-regional precipitation variability (IRPV) in NW China has been inadequate. In the present study, we base on historical flood/drought records to compile a decadal IRPV index for NW China spanned AD580–1979 and to find its major determinants via wavelet analysis. Results show that our IRPV index captures the footprints of internal hydro-climatic disparity in NW China. In addition, we find distinct ~120–200 year periodicities in the IRPV index over the Little Ice Age, which are attributable to the change of hydro-climatic influence of ocean-atmospheric modes during the period. Also, we offer statistical evidence of El Niño Southern Oscillation (Indo-Pacific warm pool sea surface temperature and China-wide land surface temperature) as the prominent multi-decadal to centennial (centennial to multi-centennial) determinant of the IRPV in NW China. The present study contributes to the quantitative validation of the long-term IRPV in NW China and its driving forces, covering the periods with and without instrumental records. It may help to comprehend the complex hydro-climatic regimes in the region.

Keywords: Precipitation variability, Asian Summer Monsoon, El Niño Southern Oscillation, Indo-Pacific warm pool, Temperature, Northwestern China

Predictability of the specific monthly-mean large-scale atmospheric anomalies over the North Pacific

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The North Pacific shows the specific monthly-mean large-scale atmospheric anomalies, even after removing the components of the northern annular mode (NAM) and the El Niño/Southern Oscillation (ENSO). This work examines the spatial structures, precursors, and development of the residual anomalies using global objective reanalysis data. The rotated empirical orthogonal function (REOF) analysis extracts the prevailing anomalies in upper tropospheric geopotential height in the northern hemisphere (NH). The first REOF mode (REOF1) is featured by a monopole in the North Pacific, while a dipole characterizes the second REOF mode (REOF2), both of which have large month to month variability. The equivalent barotropic structure characterizes the two modes, and the stationary Rossby waves form the anomalous circulations downstream. The blocking and the transient eddy (TE) are effective to maintain the two modes over the North Pacific. The precursors for REOF1 and REOF2 are detected in one month earlier; that is, there appear systematic zonal bands over Eurasia and North America in the anomaly fields of surface temperature and baroclinic instability in the lower troposphere. The later extends into the central North Pacific at different latitudes with the convergence of thermal fluxes. The anomalous zonal bands are also identified in the anomaly field of upper tropospheric geopotential height. Such systematic organization of anomalous zonal bands over the two continents reflects the ovalization of polar vortex in the upper troposphere and of polar high in the lower troposphere with the continent-ward shift of longer axis. The latitudinal difference determines which of REOF1 and REOF2 develops in the following month with the zonally guided activation of TEs over the North Pacific. The anomalies of the two REOF modes disappear by the further following month with the change of surface temperature over the two continents, while the anomalies of sea surface temperature retain in the North Pacific.

Keywords: the North Pacific, large-scale atmospheric circulations, predictability

Testing frontal air-sea interaction dynamics using spectral transfer functions

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We test a linear model for the response of the atmospheric boundary layer to variations the sea surface temperature associate with the ocean mesoscale. The model includes the impact of sea surface temperature fronts on vertical mixing and on pressure gradients, and includes advection by a background Ekman spiral. Model dynamics are governed by transfer function in wave-number space between sea surface temperature, and frontally boundary layer variables. Using output from the atmospheric general circulation model AFES, we evaluate the spectral transfer functions for frontally induced wind speed and direction. For the Southern Ocean results show encouraging agreements and suggest that the linear model captures the underlying physics. In contrast, the Kuroshio region is more challenging.

Keywords: atmosphere, air-sea interaction, sea surface temperature

The roles of latent and sensible heat fluxes in the atmospheric response to the Kuroshio/Kuroshio Extension

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It has been known that heat fluxes from extratropical SST fronts play important role for modifying the stormtrack activity and its position. (e.g. Nakamura et al. 2008; Taguchi et al. 2009). The heat flux consists of the latent and the sensible heat flux, which are released in different altitudes. To investigate their contribution for the stormtrack response, we have conducted a series of experiments for simulating the western North Pacific, using a regional atmospheric model. High-resolution SSTs are used for calculating both the latent and sensible heat fluxes in Experiment A. Low-resolution SST is used for calculating the latent heat flux in the Experiment B and for the sensible heat flux in the Experiment C. The difference between the Experiments A-B indicates the response induced by the latent heat flux from the SST front and A-C that by the sensible heat flux.
It is found that precipitation enhancement along the SST front is mostly caused by the response to the latent heat flux. The sensible heat flux induces near surface moisture convergence, but it does not contribute to the precipitation. Only the response to the latent heat flux significantly increase the storm track activity defined as high-frequency SLP fluctuation along the Kuroshio/Kuroshio Extension. Paths of cyclones are tended to be shifted by the latent heat flux toward north a few degrees. Meridional eddy heat transports due to the latent and sensible heat flux averaged along the Kuroshio Extension region take the maximum at 850 hPa and 1000 hPa, respectively. The vertically integrated heat transport due to the latent heat flux is three times larger than that due to the sensible heat flux.

Keywords: Stormtrack, SST front, Kuroshio

Climatological Monthly Frequency of the Explosive Cyclones in the Northwestern Parts of the Pacific and the Atlantic

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This study examines the climatological monthly frequency distribution of the explosive cyclones over northwestern parts of the Pacific (NWP) and the Atlantic (NWA) in the boreal cold season (October to April) from 1979/80 to 2012/13, using the long-term reanalysis data. The distributions show the different patterns between the NWP and the NWA, i.e., trapezoid in the NWP and triangle in the NWA. The difference is particularly large in March. This study reveals the physical mechanisms that yield the difference in the monthly frequency distributions, especially around March. The low-level meridional temperature gradient well explains the monthly frequencies in the two regions. The large frequencies in the NWP are maintained from February to March, and this feature can be explained by the gradient. The gradient to the east of Japan is maintained until March, because the cold air advection with the northwesterly winter monsoon is largely decreased in March, and the warmed area largely spreads from north to south of the gradient. However, in the NWA, the northerly winds are relatively weak in winter, and the cold air advection to the south of the gradient is weak. As a result, the monthly changes of the gradient fit the triangle following the simple temperature change to the north. The large-scale land-sea distribution and mountains control the strength of winter northerly winds in the NWP and the NWA, and the difference in cold air advection yields the different temperature change to the east of the two continents. This difference further forms the specific monthly changes in the low-level meridional temperature gradient, which results in the difference of the climatological monthly frequency distributions of the explosive cyclones between the NWP and the NWA.

Keywords: explosive cyclone, meridional temperature gradient, winter monsoon

Subduction of temperature anomalies of the 2013-2015 North Eastern Pacific warm “blob”

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Northeastern Pacific sea surface temperature (SST) off the west coast of North America has been extremely warm since late 2013, a record SST warming sometimes called “blob”. This study investigates subsurface oceanic changes associated with the blob using a gridded objective analysis dataset based on Argo profiling floats (MOAA-GPV) for the period 2005-2015. The MOAA-GPV data show that the warming is not confined at the surface mixed layer (ML) but penetrates into thermocline around the depth of 100-200m since the development of the blob. Decomposition of the temperature anomalies into parts associated with density anomalies and parts that are density-compensated with salinity reveals that the subsurface penetration of the temperature anomalies into the thermocline takes pace in the form of density-compensated anomalies (a.k.a. spiciness) while the density-associated anomalies are only confined in the ML. A possible explanation of this subsurface spiciness generation is a previously proposed mechanism where a temperature anomaly at the surface shifts isopycnal outcrops across mean temperature and salinity gradients and thereby alters the temperature-salinity properties on isopycnal surfaces. We will discuss how this local spiciness generation process as well as large-scale spiciness advection in the thermocline contribute to the subsurface heat penetration beneath the blob. Even after the surface blob decays, it is likely going to leave a longer-lived signature in the subsurface thermocline.

Keywords: surface warming , warm blob , spiciness , heat uptake

Predictability of the California Nino/Nina

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Predictability of a recently discovered regional coupled climate mode called the California Nino (Nina) off Baja California and California is explored using a seasonal prediction system based on the Scale Interaction Experiment-Frontier, version 1 (SINTEX-F1) coupled ocean–atmosphere general circulation model. Because of the skillful prediction of basin-scale El Nino (La Nina), the California Nino (Nina) that co-occurs with El Nino (La Nina) with a peak in boreal winter is found to be predictable at least a couple of seasons ahead. On the other hand, the regional coupled phenomenon peaking in boreal summer without co-occurrence with El Nino (La Nina) is difficult to predict. The difficulty in predicting such an intrinsic regional climate phenomenon may be due to model deficiency in resolving the regional air–sea–land positive feedback processes. The model may also underestimate coastal Kelvin waves with a small offshore scale, which may play an important role in the generation of the California Nino/Nina. It may be improved by increasing horizontal resolution of the ocean component of the coupled model. The present study may provide a guideline to improve seasonal prediction of regional climate modes for important industrial as well as social applications.

Keywords: California Nino/Nina, Seasonal prediction

Variability of South Pacific Subtropical Gyre

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Taking advantage of the decade-long Argo data, this study investigates the variability of South Pacific subtropical gyre. Both sea level and steric height exhibit a linear increasing trend in the subtropical South Pacific, with its maximum value taking place in the western part of the basin. The increase north of 30ºS is primarily caused by variability in the upper 500 m, while the increase south of 30ºS is driven by variability in the whole water depth from the sea surface to 2000 m, with contributions from below 1000 m accounting for about 50% of the total variance. Most of this linear trend is due to thermal expansion, except in the deep ocean where haline contraction is of equal importance. A spin-up of the South Pacific subtropical gyre is seen during the Argo period, and the spin-down during 2002-04 reported by previous studies is merely an interannual perturbation. Atmospheric forcing of this variability is discussed.

Trends and interannual variations of rainfall over the Indonesian maritime continent

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Trend and interannual variations of rainfall amount and rainfall extremes over Sulawesi and the Maluku Islands in the eastern Indonesian maritime continent (IMC) were investigated using surface daily rainfall data at 23 stations during 1972–2012. Tendencies towards wetter conditions seen in the rainfall extremes are predominant features in the eastern IMC in accordance with increasing trend of the relative proportion of total rainfall amount from heavy rainfall. The interannual variations of the rainfall extremes were closely related to ENSO phases. The wetter (drier) condition is associated with La Niña (El Niño) event, especially for wet days at more than 90% of the stations. Heavy rainfall events increase during La Niña years at more than 60% of the stations. On the other hand, Villafuerte and Matsumoto (2015) described that a decreasing trends of annual rainfall amount and heavy rainfall were dominant in most parts of the IMC, except the eastern part using a gauge-based gridded rainfall dataset during 1951-2007. Decreasing trends of rainfall amount were also reported over Java Island in the western IMC that might be related to the weakening of the Asian winter monsoon (e.g., Aldrian and Djamil, 2008; Hamada et al. 2012). At the meeting, we will discuss temporal and regional differences of the trends and influence of ENSO over the whole maritime continent by analyzing the surface rainfall datasets for the older period (oldest record started from the middle of 19th Century) and the entire region of the IMC.

Keywords: Maritime continent, Rainfall variability , Trends

Decadal-scale variation of the typhoon recurvature latitude

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The long-term variation of typhoon recurvature latitude was estimated based on the analysis of typhoon trajectory patterns via the Gaussian process regression technique. Since typhoon trajectory patterns affect the risks of typhoon-related hazards, it is important to model its variation. In this study, long-term variations in typical typhoon trajectory patterns were analysed simultaneously with seasonal variations. The results indicate decadal or longer meridional oscillations of typhoon recurvature points that are distinguishable from seasonal variations. Background wind field variations seemed to be consistent with the variations of the typhoon latitude recurvature after 1990, but the correspondence was poor before 1990. These results suggest that for at least the two decades after 1990, the typhoon recurvature latitude was associated with a long-term oscillation mode. The poor correlation before 1990 might suggest that meridional variations of the typhoon recurvature latitude were primarily related to central Pacific rather than the eastern Pacific warming. However, further investigation will be required to attain a conclusive answer.

Keywords: typhoon, long-term variation

Dynamical response of the North Pacific Ocean to the tropical variability and its predictability

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While teleconnections from the tropical Pacific to the North Pacific sea surface temperature are well known, the dynamical response of the North Pacific Ocean to the tropical atmosphere-ocean variability is not well investigated. Based on observed and reanalysis data, we investigate this link through a correlation analysis using the indices of Nino3, Nino3.4, and El Nino Modoki Index (EMI). The simultaneous correlation maps of the wind-stress curl indicate that the signal associated with EMI in the eastern North Pacific is stronger than the counterparts with Nino3 and Nino3.4. Responding to these signals in wind-stress curl, sea surface height (SSH) anomalies develop following EMI, but almost no SSH responses are found to Nino3 and Nino3.4. As El Nino Modoki lasts for a longer period than canonical El Nino, the stronger wind-stress curl signal to EMI drives the ocean more persistently, and induces substantial SSH signals. The induced SSH signals propagate westward to the western boundary region around 35N and affect intensity and/or latitude of the Kuroshio Extension. Predictability of this process will be also discussed.

Keywords: Teleconnection, El Nino, Kuroshio Extension

Relationship between upper ocean heat content in the Japan Sea and volume transport through the Tsushima Strait

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This study investigates the relationship between the upper (0-300m) ocean heat content (OHC) in the Japan Sea and the volume transport of the Tsushima Warm Current passing through the Tsushima Strait to the Japan Sea. We analyze a new high-resolution long-term ocean reanalysis data named FORA-WNP30 (Four-dimensional variational Ocean ReAnalysis for the western North Pacific over 30 years), in which the realistic ocean variation is reconstructed by an eddy-resolving 4DVAR ocean data assimilation system in the Meteorological Research Institute (MRI). Both the OHC and volume transports through the straits, that connect the Japan Sea to neighboring seas (the East China Sea and the Okhotsk Sea) and the Pacific Ocean, exhibit positive trends during recent 30 years. The spatial pattern of the trend in the OHC has three local maxima in the eastern part of Japan Sea, northeast of the Oki Islands in the southern part of the Japan Sea, and east of the Korea Peninsula. This feature is consistent with previous observational studies. The local maxima of the trend in the OHC are associated with changes in the flow pattern of the Japan Sea. In particular, the OHC signal at the northeast of the Oki Islands accompanies a warm eddy structure. Variation of low-pass filtered volume transport through the Tsushima Strait is largely in phase with variations of the OHC in the Japan Sea on interannual to decadal time scales, implying that the volume transport through the Tsushima Strait is one of causes for the OHC variations. However, the phase of variation of heat content at the northeast of the Oki Islands does not match with that of the volume transport well. Warm and cold eddy structures tend to appear alternately at the northeast of the Oki Islands on interannual time scale. It implies that the variation of the OHC at the northeast of the Oki Islands is affected by not only that of the volume transport but also dynamical adjustment related to the eddy structures.

Keywords: Japan Sea, Ocean Heat Content, volume transport, interannual variation, decadal variation

Influence of the Gulf Stream on the hemispheric-scale coupled atmosphere-ocean-sea ice system

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In this study, we artificially changed the path of the Gulf Stream in a global coupled GCM by slightly modifying the bottom topography around the Florida Peninsula and investigated the response of the hemispheric-scale coupled atmosphere-ocean-sea ice system.
When the narrow channel east of the Florida Peninsula is deep enough in the model, the Gulf Stream takes a realistic path around the peninsula (otherwise the Antilles Current is enhanced unrealistically), but it overshoots northward in comparison to the case with the shallower channel. As a result, positive sea surface temperature (SST) anomalies are found around the Gulf Stream "Extension" (after it separates from the east coast of the North America) and in the Barents Sea. This is consistent with the observed fact that northward shift of the Gulf Stream Extension induces positive SST anomaly in the Barents Sea. On the other hand, SST around Japan increases as opposed to the previous studies that warm anomaly in the Barents Sea brings cold anomaly over Eastern Eurasia. In our model, decrease of sea ice in the Arctic Ocean caused by the modification of bottom topography creates negative sea-level pressure anomaly that elongates along the entire Arctic rim, which may induce northward shift of the atmospheric circulation in the lower Troposphere and the subtropical gyre in the North Pacific, and hence, positive SST anomaly around the Kuroshio Extension.

